RADIOWAVE ACTIVE-PASSIVE APPROACH FOR INVESTIGATION OF THE HEAT FLUX FROM THE MARTIAN SUBSURFACE LAYERS; N.A.Armand[1], V.N. Zharkov[2], A.V. Kozenko[2], Yu.G.Tishchenko[1], A.S.Shmalenyuk[1], [1]Institute of Radioengeneering and Electronics, Moscow 103907, Russia; [2]Institute of Earth Physics, Moscow, 123810, Russia.

The using of the radiowave methods for investigation of the Earth group planets permits to receive the special data about the subsurface characteristics of planet. The receiving of these data is based on the measuring of the reflection characteristics of the martian surface depending on its dielectric permitivity. However, these measurings do not permit to receive the direct data about the thermal characteristic of the Mars, one of the significant characteristics of the planet. For example, for determining parameters of model of water and thermal balance, the internal thermal flux of planet is requested, it is one of the main characteristics. Up-to-date data about the planet thermodynamic characteristics give unsufficient estimation of this parameter. In present paper radiowave passive approach is proposed to be used in jointly to active one for investigation of the martian subsurface characteristics. The temperature profile and estimation thermal flux are extracted from radiometric measurements on few waves. The using active approach give the possibility of deriving permitivity and reducing influence of the surface characteristic on the accuracy of the temperature estimation. Results of quantitative estimation of wavelength selection are presented. The region with low content of ice in upper surface layers must be selected for measuring thermal flux. The using measurements only on two wavelengths of meter and decimete wave band allow to particularize the present data about thermal flux. For other martian regions with high ice content active-passive measurements permit to receive surface map of radiophysical data connected with salt, water content, diurnal cycle parameters. The using of these methods is connected with relatively small energy consumption, mass-size parameters. The use of the achievements in the radiophysical investigations technique will allow to create the space complex for the investigation of Mars. One of the main goals of this presentation is the estimation of possibilities of using active-passive approaches for determination of martian thermal flux.

Radiometric approach is based on measuring self microwave thermal emission of medium. The value of this emission is proportional to integral physical temperature of subsurface layer and depends on radiophysical characteristics of surface. The effective thickness of subsurface layer is proportional to wavelength. The multiwave measurements allow to determine subsurface temperature profile. The radiometric measurements on two wavelengths allow to derive the temperature gradient. The difference (DT) of radiobrightness temperature on two wavelengths depends on the gradient (GDT) as follow [1,2]:

$$DT = TP2 - TR1 \sim E \bullet GDT \bullet (L2 - L1) \qquad (1)$$

where TR1, TR2 - radio brightness temperature on a wavelength 1 and 2, E - emissivity of surface, L1, L2 - penetration depth on wavelength 1, 2. Last value is defined as [3]:

$$L = \lambda/(4\pi \mathrm{Im}(\sqrt{\varepsilon})) \qquad (2)$$

where λ - wavelength, ε - dielectric constant of medium, $\mathrm{Im}(\sqrt{\varepsilon})$ - imaginary part of square root of complex dielectric constant. Model of martian subsurface structure is described in [4]. Analysis of the models have showed that for depth up to 400 m the subsurface structure is close to homogeneous. The depth of radiowave penetration is maximum for places with low content of ice. The estimation of these depths are shown in the table 1. As follow from the table the homogeneous model is valid for frequency up to 0.01 GHz. This model has been used for deriving estimation of possibilities of determination of temperature profile gradients with radioetric approach.

Table 1. Estimations of radiowave penetration depth

Frequency	Depth of radiowave penetration
1 GHz	4.8 m
0.5	9.5 m
0.1	47.8 m
0.01	478 m

The results of these estimations are shown in table 2. The measurable precision of temperature gradient depend from using wavelength range and precision of radio brightness estimation. The precision is increased with enhancing wavelength range and increasing of precision of radiometric measurements. The estimation have been made for wavelength range and precision which can be realize at present. The difficulties of technical realization are growing with enhancing of wavelength range. The estimations have been made for measurable precision of radiobrightness temperature from 0.1 K to 0.5 K. Last value is possible due to influence of roughness. The technical realizing precision of microwave radiometric measurements of radiobrightness temperature is less 0.1 K.

Table 2. Estimation of precision of temperature gradient measurements

Wavelength range	Precision of radiobrightness temperature	Measurable precision of temperature gradient
0.3 - 1.5 m	0.1 K	10 K/km
	0.2 K	20 K/rm
	0.3 K	30 K/km
0.3 - 2.7 m	0.1 K	5 K/km
	0.2 K	10 K/km
	0.5 K	25 K/km
0.3 - 5.1 m	0.1 K	2.5 K/km
	0.2 K	5 K/km
	0.5 K	12.5 K/km

As follow from the table 2 the radiometric measurements with wavelength 0.3–1.5 m and precision 0.2 K allow to determine the temperature gradient with precision 20 K/km.

Modern estimation of the temperature gradient in the martian crust under the regolite layer is ~5–20 K/km. In the regolite layer one grow up to ~50 K/km and more. Hence the measurements of the temperature gradient with precision 20 K/km are should not be sufficient. Measurements on wavelength range 0.3–5.1 m enable to derive the precision of the gradient estimation up to 5 K/km for precision of radiometric measurement 0.2 K and up to 2.5 K/km for precision 0.1 K. The using active approach in conjunction with passive one allow to determine radiophysical characteristics of surface and hence to decrease influence of surface parameters including roughness. In result the precision of gradient estimation is increased. The radar measurements allow to derive the estimation of dielectric constant too. Then the using the relation between dielectric constant and thermal conductivity it is possible to refine thermal conductivity which is necessary for estimation of thermal flux.

The analysis presented here leads to conclusion that the radiometric measurements allow ones to derive the estimation of thermal heat flux with precision required for practical applications. The required precision of radiometric measurements is technically realizable. The spaceborne radiometric measurements will give map of thermal heat flux of Mars. These enable to determine place with high thermal gradient. The precision of measurements can be increased in case of measurements close to martian surface with using landed spacecraft and vehicles.

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